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CONSIDERATIONS FOR REDUCING THE COST OF TESTING DREDGED MATERIAL

by

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The high cost of chemical analyses and bioassays of dredged material makes it necessary for decision makers to limit testing to that which will sufficiently characterize the sediment to evaluate a selected disposal alternative. This report offers guidance for limiting the amount of testing necessary and considers other factors that could potentially reduce the cost of testing dredged material.

The importance of an initial site evaluation to reduce the extent of dredged material testing is stressed. Unless a reason to believe that contamination exists can be established through examination of historical data and other site characteristics, no testing is warranted. The need for testing can sometimes be eliminated by examination of regulatory criteria for categorical exclusions, i.e., circumstances under which no testing is required. Additional cost savings can sometimes be generated during the scoping process by amelioration of the concerns of interested parties prior to preparation of an environmental impact statement.

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Tiered testing as presented in the Federal Standard is recommended as a cost-reduction approach to material evaluation. The principal advantage of tiered testing is that it can be stopped when sufficient information has been acquired to make a decision regarding the suitability of a given disposal alternative.

In developing a sampling plan, consideration should be given to stratified random sampling, compositing, archiving, and use of a risk factor when determining the number of samples needed. All of these considerations, when applied under appropriate circumstances, can result in cost savings. Two factors that could potentially reduce the cost of chemical analysis are careful contract laboratory selection and the use of screening tests and representative analytes.

Cost reduction can be achieved in testing dredged material to determine the suitability of a selected disposal alternative by carefully considering the options. The greatest cost reduction will result from the exercise of informed judgment concerning such factors as the significance of site history, the precision and resolution of the sampling design, and the acceptable degree of risk that the sampling will miss contaminated areas.

PREFACE

This report was prepared by the Environmental Laboratory (EL) of the US Army Engineer Waterways Experiment Station (WES), Vicksburg, MS, under the direction of the Dredging Operations Technical Support (DOTS) Program. Dr. Robert M. Engler is the DOTS Program Manager. Mr. Thomas R. Patin is coordinator for the DOTS Program. Personnel of the Contaminant Mobility Research Team who participated in the preparation of the report are: Dr. Judith C. Pennington, CPT Todd R. Higgins, Dr. Bobby L. Folsom, Jr., and Mr. Dennis L. Brandon. Drs. Thomas D. Wright, James M. Brannon, and Robert H. Kennedy are acknowledged for their review of the manuscript. Preparation of the report was under the general supervision of Dr. Lloyd H. Saunders, Chief, Contaminant Mobility and Regulatory Criteria Group; Mr. Donald L. Robey, Chief, Ecosystem Research and Simulation Division; and Dr. John Harrison, Chief, EL.

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CONTENTS

CONSIDERATIONS FOR REDUCING THE COST OF TESTING DREDGED MATERIAL

PART I: INTRODUCTION

Background

1. Over 90 percent of the total volume of sediment that is dredged annually by the Corps of Engineers is uncontaminated and can be properly disposed of using a variety of disposal options (Peddicord et al. 1986). However, potential for contamination at some sites, e.g., those located near industrial and urban areas, must be evaluated. Testing of this material is essential so that it may be disposed of in a manner that is consistent with environmental and regulatory mandates. The cost of chemical analyses and bioassays is high. Fortunately, the principal objective of such testing is not necessarily a comprehensive characterization of contaminants in the sediment, but a sufficient characterization, which may or may not be comprehensive, to make the appropriate decision concerning the suitability of the material for the selected disposal option. Guidance exists for making decisions concerning disposal of dredged material suspected of being contaminated. Much of this guidance includes limitations on the amount of testing that is necessary and appropriate. These limitations, as well as other potential cost-saving considerations, will be discussed in this report.

Objective

2. The objective of this report is to outline procedures that will reduce the cost of dredged material testing while providing an appropriate evaluation of the potential environmental impact of dredged material disposal. Careful attention to three factors that are presented in the report can result in cost reduction during site evaluation. The first concerns the necessity for analysis. The second is use of a tiered testing approach to limit the amount of testing and to tailor the testing to a specific material. Finally, several considerations are presented for limiting sampling and the cost of sample analysis.

PART II: INITIAL EVALUATION

Establishing a Reason to Believe That Contamination Exists

3. Guidance set forth in 40 Code of Federal Regulations (CFR) 230 specifies that an initial evaluation of dredged or filled material be conducted to determine if there is "reason to believe that any dredged or fill material to be discharged into waters of the United States contains any contaminant above background level." To that end, further guidance in the document lists factors that can be considered. This same general guidance applies equally to material proposed for ocean disposal (40 CFR 227). Factors to consider when evaluating a site include potential routes of introduction of specific contaminants, evaluation of historical data, and the probability of past substantial introduction of contaminants from various sources (e.g., land runoff, spills, or industrial discharge). The Code also specifies that "if there is no information indicating the likelihood of such contamination, the permitting authority may conclude that contaminants are not present above background levels." Therefore, the Corps, as "permitting authority," is explicitly and exclusively charged with an evaluation of what constitutes a reason to believe that contaminants are present. When the evaluation indicates no reason to believe that contamination exists, no testing should be done. Time expended in the careful scrutiny of historical data, site maps and/or aerial photographs that show watercourses, surface relief, proximity to roads, storm drains, agricultural fields, highways, and industries may produce significant savings by completely eliminating the need for chemical or biological testing. If not eliminated completely, testing may be restricted (based on the initial evaluation) to one or a few contaminants, and to a small portion of the material to be dredged.

4. The importance of avoiding unnecessary testing by first establishing a reason to believe that contaminants are present is stated in 40 CFR 230 and stressed again in a technical note, "Corps of Engineers' Procedures and Policies on Dredging and Dredged Material Disposal (The Federal Standard)" (Engler et al. 1988), which summarizes the Corps' guidance to field offices nationwide. A proper initial assessment of reason to believe that contamination exists is recognized as crucial to project cost minimization. Testing for the placation of outside interests, or to meet research and data base demands, is inappropriate.

5. Essentially no need exists for testing material that is categorically excluded. For ocean disposal, minimal testing is required on the material described below.

> (b) Dredged material which meets the criteria set forth in the following paragraphs (1), (2), (3) is environmentally acceptable for ocean dumping without further testing under this section:
> (1) Dredged material is composed predominantly of sand, gravel, rock, or any other naturally occurring bottom material with particle sizes larger than silt, and the material is found in areas of high current or wave energy such as streams with large bed loads or coastal areas with shifting bars and channels; or
> (2) Dredged material is for beach nourishment or restoration and is composed predominantly of sand, gravel or shell with particle sizes compatible with material on the receiving beaches; or
> (3) When: (i) The material proposed for dumping is substantially the same as the substrate at the proposed disposal site; and
> (ii) The site from which the material proposed for dumping is to be taken is far removed from known existing and historical sources of pollution so as to provide reasonable assurance that such material has not been contaminated by such pollution.

40 CFR 227.13(b)

6. In addition, material proposed for discharge into the waters of the United States which meets the conditions below need not be tested.

> (b) *Category 1: Discharge Without Potential for Environmental Contamination.* (1) Dredged material falls into Category 1 when the initial evaluation does not indicate the presence of contaminants in the dredged material above background levels. Consequently, the only concern is the direct physical effects of the material to be discharged, and there is no need to compare this material chemically to sediments at the proposed disposal site. Dredged material which is composed predominantly of sand, gravel, shell or other naturally occurring sedimentary material with particle sizes predominantly larger than silt is likely to, but does not always, qualify for inclusion under Category 1. Generally, these materials are characteristic of areas of high current or wave energy, such as streams with large bedloads or coastal areas with shifting bars and channels. However, noncontaminated fine-grained materials may also be shown by the precategorization elevation to meet the conditions of Category 1. No chemical or biological testing is required to make the factual determination.

40 CFR 230.62(b)

7. Prior to any testing, the District Commander should be sure that the material does not fall into the categories above.

8. The 33 CFR 230 on procedures for implementing the National Environmental Policies Act (NEPA) also lists certain actions that do not have significant effect on the quality of the human environment and are categorically excluded from NEPA documentation. These actions include minor maintenance dredging using existing disposal sites.

Site Histories

9. Evaluation of historical data for a proposed dredging site can result in substantial cost savings by eliminating the need for testing, by limiting the number of contaminants for which tests must be conducted, and/or by limiting the amount of dredged material that must be tested. The value of historical data is controlled by its reliability, which in turn depends upon the quality, timeliness, and completeness of the data. For example, if sediment chemistry data are to be useful, they must be accompanied by information about the extent, location, and depth of sampling, method of sampling, laboratory quality control and detection limits, and dates of sampling.

10. The consensus of Higgins (1988) was that data taken in areas where active sources of contamination exist are relatively reliable if less than 2 years old, and that data taken in areas where no active sources of contamination exist are relatively reliable if less than 5 years old. Reliable historical data provide an invaluable basis for reducing costs by eliminating or limiting chemical and/or biological testing of sediments.

The Scoping Process

11. According to 33 CFR 320-330, if an initial evaluation such as examination of site histories results in a decision to prepare an environmental impact statement (EIS), a notice of intent will be widely distributed to invite the public to participate in a scoping process. In the scoping process public concerns on issues, studies needed, alternatives to be examined, procedures, and other related matters are addressed. The intention of the scoping process is to prepare a concise EIS that clarifies the significant issues to be addressed as perceived by all parties and participants. Cost

savings engendered by the scoping process can be significant. If an accurate assessment is made as to whether there is reason to believe that contaminants are present, issues that could affect subsequent courses of action will be eliminated.

PART III: TIERED TESTING

12. Initially evaluating existing information and determining if there is a reason to believe that contamination is present constitute tier I of the tiered testing approach recommended by the Corps as a part of the Federal Standard (Table 1) (Engler et al. 1988). A tiered approach to decision making for disposal of contaminated dredged material is also presented in an expanded framework by Peddicord et al. (1986). Following the tiered approach can afford cost savings in establishing whether there is reason to believe that contamination is present, as well as in additional areas.

Table 1

Summary of Tiered Testing Approach for Aquatic Disposal

Tier I	Initial evaluation of existing information and of reason to believe there is contamination.
Tier IIA	Bulk sediment inventory.
Tier IIB	Elutriate analysis.
Tier III	Biological tests.
Tier IIIA	Acute bioassay toxicity tests (as appropriate).
Tier IIIB	Bioaccumulation.

13. In tier IIA, an inventory of bulk sediment contamination is made. The inventory is limited to contaminants of concern, which often include heavy metals, polychlorinated biphenyls (PCB's), polynuclear aromatic hydrocarbons (PAH's), pesticides, or other substances of ecological or human health significance. However, contaminants of concern may be limited by results of the initial evaluation. If water quality criteria are available for all contaminants of concern, and no synergistic or additive effects are expected, tier IIB, elutriate testing, can be implemented. However, if results of elutriate testing, after consideration of mixing, fail to meet the water quality criteria, a waiver must be obtained before dredging and disposal can proceed. Furthermore, if trace contaminants are present, biological testing is necessary under ocean dumping criteria (40 CFR 227.6).

14. Alternatively, tier III, biological testing can be implemented. If results of bioassays indicate no adverse effects, the material is assumed to also pass elutriate tests even though none were conducted. Prior to conducting water column bioassays, consideration should be given to the fact that the primary disposal impacts are on the benthic community. With regard to the benthic community, if the material is suspected of being toxic, of containing contaminants which may bioaccumulate, or of containing trace contaminants (40 CFR 227.6), solid phase testing is needed. In addition, if the dredged material contains contaminants above background levels and the contaminants are suspected of being bioavailable, solid phase bioassays may be needed (40 CFR 230.62).

15. An important advantage in the use of tiered testing is the potential it affords to limit testing at a point where sufficient information has been acquired to make a decision regarding the appropriate dredged material disposal alternative.

PART IV: SAMPLING AND SAMPLE ANALYSES

16. Approaches to development of sampling plans are necessarily governed by characteristics and objectives of specific projects. The approaches to sampling plan development that are discussed below are not all-inclusive, but rather exemplify procedures having cost-reduction potential. Stratified random sampling, compositing, and archiving are frequently applied as a means of reducing the number of samples tested. Treating the distribution of contaminants in the area to be sampled as spatially dependent, i.e., assuming that concentrations at any one point are more similar to concentrations at adjacent points than at remote points, is a technique only recently applied to environmental contamination, and is discussed because it has potential relevance to future testing protocols. While reduction in the cost of chemical analyses is best achieved by reducing the number of samples, several other potentially cost-saving factors associated with chemical analyses are also considered. These factors include selection of a competent contract laboratory, specifying detection limits, and the use of screening tests and representative analytes.

Sampling Plan Approaches

17. The characteristics of a sampling plan necessarily depend on site-specific considerations. A poll of District personnel (Higgins and Lee 1987) indicated that most Districts rely upon only a few factors when deciding where and how deep to sample, and how many samples to collect for bulk sediment characterization. Most Districts make an attempt to collect representative samples, the locations of which may be influenced by locations of industries or other potential point sources of pollution. Many Districts sample along a transect that runs through the center of the project, or a specified distance from the project boundaries, and may sample on shoals perpendicular to the transect. Usually sediment surfaces are sampled, but the type of dredge to be used should be considered before deciding how to sample. For example, if a dredge grabs a 1-m sample at a time, finer resolution by subdividing samples is unnecessary. The number of samples is usually determined by the size of the project in cubic yards or in square feet of sediment surface. All of these approaches possess validity when properly applied, but are not always designed to limit sampling to what is essential.

18. When contamination is suspected, the amount of sampling is sometimes increased in an effort to document the extent and degree of contamination. For this reason, and because testing of sediments for contamination represents a substantially higher cost than testing for most other purposes, project costs can increase dramatically. The remainder of this discussion will deal with testing of sediments that are suspected to be contaminated.

19. In looking for contamination in sediments, a trade-off always exists between the number of samples collected and the risk of missing a contaminated area: the larger the number of samples, the smaller the risk. The most promising way of reducing the number, and consequently the cost, of sediment chemical analysis is to develop a defensible sampling plan that takes into account all of the information available concerning potential location, depth, and characteristics of the contaminants as well as dredging requirements. Several approaches to sampling and to handling samples and data that can provide scientifically valid contaminant distribution data and that possess potential for reducing the number of samples necessary, thereby reducing costs, are discussed below. Each of them has both strong and weak points and must be evaluated for the specific conditions under which it is to be applied.

Stratified random sampling

20. Random sampling in which a grid is placed over a map of the area to be sampled and a random number of grids are selected for sampling is often recommended because the method increases the statistical accuracy of sediment characterization. However, taking this approach without consideration of shoaling, historical data, or location of potential point source discharges of contaminants can result in analysis of too many samples. A more appropriate method may be stratified random sampling in which a grid is employed, but allowances are made for factors that are likely to affect the distribution of contaminants. While concentrating the sampling in areas having high potential for contamination, the design does not completely omit areas having less potential for contamination. A statistically based number of samples can be obtained with the stratified random design, while analyzing fewer samples than with a completely random sampling design.

Spatially dependent data

21. Another procedure for potentially reducing the number of samples is to treat the data as spatially dependent. The statistics applied to analysis of contaminant data are usually based on the assumption that observations are

independent. However, contaminant data are always spatially dependent at some scale; that is, over some range of distances measurements will tend to be more similar to measurements taken nearby than to measurements taken farther away (Englund 1987). This is true because "processes that control the fate and transport of chemicals in the environment do not operate at random, although most events include what may be considered random processes..." (Englund 1987). A statistical method adopted from geology treats the distribution of contaminants as spatially dependent and produces a distribution model with a limited amount of field data. The model can then be used to interpolate contaminant concentrations in grids that were not actually sampled. Decisions such as the size of the grid and the maximum number of samples that can be taken and analyzed must be made before this statistical method can be employed. The proposed 4th edition of US Environmental Protection Agency (USEPA) guidance document SW-846 is titled Test Methods for Evaluating Solid Waste (for 3rd edition, see USEPA 1986). This document is expected to be published in mid-1990 (Warren 1987) and will include guidance on the application of spatial statistics and methods for optimizing grid sizes for use in the procedure.

Compositing and archiving

22. Under some circumstances, collecting many samples, compositing subsets of these, and archiving, or storing, the discrete samples is cost-effective. The greatest cost savings result from limiting the number of sampling trips. For example, collection of many sediment samples may cost as much as collection of only a few if the boat, crew, and sampling equipment are paid by the day. All the samples may be taken in a single trip and kept for analysis later. If the necessity arises for expanding the number or type of analyses, use of archived samples avoids the necessity for additional sampling trips.

23. Occasionally, archiving (as opposed to immediate testing) proves cost-effective. If the time from sample collection to actual dredging is long and the samples no longer accurately represent the contaminant status of the site, analysis of archived samples cannot be done and the site must be resampled. Although not always possible, careful timing of both sampling and sample analysis are cost-effective.

24. If the distribution of contaminants in the area to be dredged is completely unknown, analysis of a few composite samples may indicate areas of greatest contamination. Limiting analysis of the archived samples to areas

where composite analysis indicated highest contamination may then provide information sufficient to characterize the sediment. Higgins (1988) suggested that compositing can be based on the probability of reason to believe that contamination exists. If, based on initial evaluation, the probability that the sediment is contaminated is assumed to be low, e.g., less than 30 percent, a composite may produce sufficient characterization. When compositing, the potential exists for diluting a hot spot; therefore, results from composite analysis must be interpreted with caution. Compositing is inappropriate when sediment must be examined for oxidation/reduction status, volatile contaminants, and certain engineering and geological properties because the properties of interest are destroyed by disturbance, e.g., mechanical mixing, of the sample.

25. General guidance on storage time for sediments prior to chemical analyses or bioassays has often been based on the minimum amount of time practical to collect and handle the samples rather than on effects storage may exert on test results. For example, the USEPA/Corps Implementation Manual (1977) recommends a storage period "as short as possible to minimize changes in the characteristics of the dredged material" and that "samples be processed within two weeks of collection." Many sediment samples are stored under conditions specified by the USEPA/Corps Implementation Manual (1977), that is, at 4° C in the dark in sealed containers not allowed to dry out. Samples taken for analysis of total metals, PCB's, etc., often are held longer than those taken for more specific analyses. However, results of recent studies conducted at the US Army Engineer Waterways Experiment Station (WES) (Tatem, Brandon, and Lee, in preparation) suggest that sediment may be stored for considerably longer than two weeks, depending on the testing to be conducted, without adversely affecting certain analyses.

Chemical Analyses

26. The cost of sediment analysis for the presence of chemical contaminants varies greatly with the chemical of interest, the method of analysis, and the specific analytical laboratory conducting the analysis. Obtaining data that are sufficiently accurate and reliable for the purpose of the project while minimizing costs requires careful consideration of these factors. In the following sections, selection of contract laboratories and

use of appropriate detection limits, screening tests, and tracer congeners/ components are discussed.

Contractors

27. Generally, selection of a contractor several months in advance and advising him of the number of samples and types of analyses needed will result in cost savings. Unexpected changes in the work load or schedule are usually accompanied by additional charges.

28. During a workshop on reducing the cost of dredged material evaluation (Higgins 1988), participants with experience in contracting for chemical analysis of sediments noted that bids submitted by different contractors often differ by as much as a factor of ten. The consensus of the participants was that extremely high bids and extremely low bids should be viewed with equal suspicion, because either could indicate a lack of experience in the contractor.

Detection limits

29. As the detection limits requested from an analytical laboratory decrease, the cost of the analysis often increases. Furthermore, the lowest possible detection limits may not be necessary. As detection limits decrease, the reproducibility of detection at that level decreases (Horwitz, Kamps, and Boyer 1980), a situation which can lead to data of questionable value. The appropriate detection limits are those set by criteria, or, in certain instances, background concentrations. No legitimate purpose is served by purchasing lower detection limits than required by the decision maker. Prior to contracting for chemical analysis, a decision should be made regarding necessary detection limits.

Screening tests

30. Screening tests for the presence of groups of contaminants will avoid assaying for a large number of specific compounds or elements. Screening tests can be particularly cost-effective for organic contaminants. In the 1987 working group (Higgins 1988), the sediment analysis task group suggested several screening techniques that can be useful to determine the presence of specific groups of contaminants in sediments (Table 2). The use of screening techniques must be accompanied by an understanding of their limitations and a conservative interpretation of their results.

Tracer congeners/components

31. The use of single compounds or congeners as tracers for a group of organic contaminants can be useful only where a correlation between the

Table 2

Sediment Contaminant Screening Tests Recommended by the 1987 Working Group on Reduction of Cost of Sediment Analyses

Technique	Cost/Sample FY 87, $	Contaminants	Detection Limits
Particle size	30-50	--	--
UV-Fluorescence	25-100	PAH's	ppb-ppm
Total organic halogens	25-100	Halogenated organics	ppm
Inductive coupled plasma	50-150	Most metals	ppb-ppm
High performance thin layer chromatography	50-150	Organics	ppb-ppm
Fast GC-methods (e.g., USEPA 5020)	50-75	Organics	ppb-ppm
Total organic carbon	20-30	Organics	ppm
Tracer congeners/components*	--	PCB's, PAH's	ppb-ppm
Tracer metals*	--	Metals	ppb-ppm

* Selection of specific variable(s), or tracer(s), based on historical data. Sediment characterization by tracer is confined to specific sites where the tracer is well-established as representative of the group of contaminants of concern. (See discussion of tracers below.)

presence of the tracer and other analytes has been established. The determination of a single analyte may not always be cost-effective because analysis of a single compound is sometimes as expensive as analysis of the whole group.

32. In a workshop held at WES in March 1987, tracer compounds were specified for the analysis of petroleum hydrocarbons in dredged material (Clarke and Gibson 1987). The consensus of workshop participants was that oil and grease analyses do not provide a meaningful summary measure of hydrocarbon contamination in sediments, a conclusion shared by the 1987 chemical cost reduction working group; however, analyses for all petroleum hydrocarbons individually is prohibitive in terms of cost, data interpretation is difficult, and the results are of little use in decision making. Participants recommended that aliphatic hydrocarbons be excluded from regulatory evaluations because they pose analytical difficulties and generally do not cause major environmental impacts in the context of dredging and disposal. Polynuclear aromatic hydrocarbons (PAH's) were considered the most important class in dredged material due to their toxicity and persistence. Participants

recommended analyses of 15 of the 16 PAH's on the USEPA priority pollutant PAH list (Table 3). The single exclusion is naphthalene. Naphthalene was considered too volatile to give accurate analytical results and too water soluble to persist in sediments. Participants submitted that high levels of naphthalene would be manifested as mortality in acute toxicity bioassays.

Table 3

Polycyclic Aromatic Hydrocarbons (PAH's) Recommended* for Analyses to Represent Petroleum Hydrocarbons in Regulatory Evaluation of Dredged Material

Acenaphthene	Chrysene
Acenaphthylene	Dibenz(a,h)anthracene
Anthracene	Fluoranthene
Benzo(a)anthracene	Fluorene
Benzo(a)pyrene	Indeno(1,2,3-cd)pyrene
Benzo(b)fluoranthene	Phenanthrene
Benzo(g,h,i)perylene	Pyrene
Benzo(k)fluornathene	

* Recommended by "Regulatory Identification of Petroleum Hydrocarbons in Dredged Material" workshop participants (Clarke and Gibson 1987).

33. Clarke, McFarland, and Pierce (1989) suggest that evaluation of PCB-contaminated dredged material for regulatory purposes can be most effective when samples are analyzed for specific PCB congeners. They further suggest that chemical and/or biological testing be limited to those congeners that possess potential for unacceptable adverse ecological impacts due to prevalence in the environment, preferential bioaccumulation, or potential toxicity, and have prepared a list of 36 congeners prioritized on these bases (Table 4). Group 1, the highest priority congeners, includes congeners most likely to contribute to adverse biological effects and is subdivided into two groups; 1A and 1B, depending on toxicological properties. Group 2 includes congeners having numerous reported environmental occurrences. Group 3 PCB congeners are of moderate priority because they are toxicologically weaker than those placed in the previous groups. Group 4 contains congeners having few reported environmental occurrences.

Table 4

Priority Groups of PCB Congeners of Highest Concern as Environmental Contaminants

Group 1	Group 2	Group 3	Group 4
A			
77[ab]	87[ab]	18[a]	37[b]
126[b]	99[b]	44[abc]	81[c]
169[bc]	101[abc]	49[abc]	114[abc]
	153[ab]	52[abc]	119
B	180[ab]	70[b]	123
105[ab]	183[abc]	74[b]	157
118[ab]	194[ac]	151[ac]	158[b]
128[abc]		177[c]	167
138[abc]		187[ac]	168
156[ab]		201[a]	189[abc]
170[abc]			

[a] Congeners included in Canadian Standard CLB-1. The remaining congeners making up CLB-1 are given by Clarke, McFarland, and Pierce (1989).

[b] Congeners suggested for inclusion in a selective congener analysis for human foodstuffs and tissues. Others are listed by Clarke, McFarland, and Pierce (1989) and Jones (1988).

[c] Identified as prevalent congeners that elute (or probably elute) as single-congener peaks from a single SE-54 glass capillary column using GC/EDC. Others are listed by Clarke, McFarland, and Pierce (1989) and by Duinker, Schultz, and Petrick (1988).

34. One limitation on the use of the recommended list (Table 4) is difficulty in chemical analyses. Only 16 of the 36 congeners can be subjected to unambiguous analysis by conventional means (Clarke, McFarland, and Pierce 1989). Another limitation on the use of the list is its basis in mammalian microsomal enzyme induction toxicology. Use of this enzyme induction test for assessing toxicity potential for nonmammalian species has not been fully validated.

Bioassays

35. Bioassays are a basic tool in an effects-based testing protocol as required by applicable environmental legislation and are used for assessing

real impacts of contamination on the environment. Reduction in the cost of bioassays may be achieved by careful management, e.g., selecting a competent laboratory, implementing a strong quality assurance/quality control program to increase confidence in the data obtained, and tailoring the tests to address site-specific concerns.

36. Frequently, organisms that are obtained locally may be more economical and representative than those obtained from outside the region. However, only organisms for which a body of experience, or data, has been developed should be used to insure that the bioassay will not have to be repeated because of uninterpretable results.

Part V: SUMMARY AND CONCLUSIONS

Summary

37. Seldom will Corps personnel utilize all of the strategies mentioned in this report on any given site. Only the strategies that most efficiently maximize the evaluation of the individual site should be employed. Site history and/or a site survey should be used to stratify the site vertically, horizontally, or both. These strata will be dictated by initial site evaluation such as proximity to contaminant sources.

38. The decision to use composite samples, screening tests, and/or bioassays, as well as determination of the number of samples and types of analyses should be made for each stratum. Some of these decisions also affect the quantity of sample collected. For example, if both chemical analyses and bioassays are needed, larger quantities of sediment must be obtained at the first sampling so that results of all tests can be compared. A risk that is consistent with the properties of each stratum should determine the number of samples. The use of composite samples may effectively lower the risk without increasing costs. A separate list of contaminants, screening tests, and/or bioassays should be prepared for each stratum. Additional techniques, such as treating the data as spatially dependent, may be viable within strata. Use of strata also distinguishes areas of high contamination from areas requiring less restrictive disposal.

Conclusions

39. The cost of testing dredged material can be controlled by the considered implementation of a series of decisions. All too often appropriate use is not made of exclusion clauses that can effectively exempt material from testing. In establishing whether there is reason to believe that contaminants exist, common sense should be employed and all available data and information should be extensively evaluated to eliminate or reduce costs resulting from technically unjustifiable recommendations or requirements from other agencies. In these instances, strict adherence to the Federal Standard will avoid these impositions.

40. Absolute adherence to set procedures for sampling, testing, and evaluation (except those required by regulations) should be avoided.

Generally, the regulations provide sufficient flexibility to assure adequate environmental protection at affordable costs.

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